US Army Corps of Engineers

Construction Bulletin

No. 95-19 **Issuing Office:** CEMP-CP **Issue Date:** 8/10/95 **Exp. Date:** 31 Dec 97

CEMP-C

Subject: Electrical Safety

Applicability: INFORMATION

1. In the United States, approximately 1000 deaths occur each year from electrocutions. Another 30,000 non-fatal electric shocks also occur each year. Many of these individuals were not working on electrical tasks when the electrocution occurred. Historically, electrocution is the second highest cause of contractor fatalities on Corps projects. The human body is not a good electrical conductor. However, when subjected to electrical current of sufficient magnitude at a voltage high enough to overcome its resistance, it is easily damaged.

2. Current, expressed in amperes or milliamperes, is the killing factor in electrical shock. It is accepted that 5 milliamperes is the maximum harmless current intensity to which the average human can be subjected. This 5 milliamperes is the value (± 1ma) required for ground fault circuit interrupter settings as specified in UL Standard 943. At 1 to 8 milliamperes, there is a sensation of shock but the sensation is not painful and there is no loss of muscular control, i.e. the individual can let go of the energized item at will. At 8 to 15 milliamperes, painful shock is experienced, but muscular control is not lost. At 15 to 20 milliamperes, painful shock is experienced and muscular control in the portion of the body adjacent to the point of shock is lost. At 20 to 50 milliamperes, severe muscular contractions are experienced together with a difficulty in breathing. At 100 to 200 milliamperes, a condition known as ventricular fibrillation can occur. This is a heart condition with no known remedy which results in death. At over 200 milliamperes, muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock are experienced. The individual is usually severely burned at this current intensity also.

3. Voltage, expressed in volts, is important because it determines how much current will flow through a given body resistance. Voltage represents pressure to enable the current to

given currrent intensity to harm the human body. Approximately 10 times more electrocutions are caused by high voltage (above 600V) shocks than by low voltage (up to 600 V) shocks.

4. Resistance, expressed in ohms, represents the impedence within a given body which resists the flow of current through that body. The main defense of the human body against electrical shock is the skin. Human skin resistance varies widely as a function of the moisture present in and on its various layers. Dry skin has a resistance of between 100,000 and 600,000 ohms. Damp and wet skin only has a resistance of between 500 and 1000 ohms. Internal body resistances are even lower, depending on the path of the electrical shock. Skin resistance also varies somewhat with age.

5. As previously stated, current is the lethal element in electrical shock with resistance and voltage as contributing parameters. The relationship between current, voltage and resistance is expressed in Ohm's Law which states that, within a given circuit, the electric current is directly proportional to the voltage and inversely proportional to the resistance ($I = V/R$). Using this formula and the values from the preceding paragraphs, it is easy to determine that the current required to operate a 15 watt light bulb at 120 volts, 60 Hz is sufficient to cause ventricular fibrillation. The duration of the electric shock as well as its path through the human body also determines the severity of the shock. Many times a victim of electric shock is not electrocuted because the current path through his body did not contain a vital organ or the duration of the shock was extremely short. During electric shock, the skin's resistance is overcome or breached by the electric current and the body's tissue, bones and vital organs become the current conductors. As the shock continues, the resistance continues to drop and the current increases with increasing internal injury. Thermal burns are external, but electrical burns are internal and far more serious. Human tissue is destroyed at a temperature of 122 degrees F. A 120 V, 15 A, 60 HZ circuit can generate in excess of this temperature in a short duration. In addition, recent research indicates there are also what are considered mid and long-range effects which can be experienced by someone who appears healthy following an electrical shock. Among these are paralysis, muscular pain, headache, loss of taste, vision abnormalities and cardiac irregularities.

6. On low voltage electrocutions, slightly less than half of the fatalities resulted from individuals working on energized ("hot") equipment or circuits. The remainder were primarily caused by defective power tools, faulty electrical cords, defective outlets and electric lights. On high voltage electrocutions, approximately 30 percent of the fatalities involved electrical work with the remaining 70 percent involving non-electrical work.

7. A review of the preceding statistics would indicate that half of the low voltage accidents and almost one-third of the high voltage accidents could have been prevented by working strictly on deenergized circuits. Unfortunately, many workers have been electrocuted by circuits which they thought were "dead". This serves to illustrate the importance of ensuring that testing is conducted to prove circuits are deenergized, and

correct lockout/tagout procedures are followed. EM 385-1-1, Safety and Health Requirements Manual is quite specific in its recommendations on performing work on energized circuits. In Section 11, Paragraph 11.A.02. b., it states, "whenever possible, all equipment as well as circuits to be worked on shall be de-energized before work is started and personnel protected by clearance procedures and grounding". It should be noted that electrical equipment and lines are to be considered energized until they are determined to be deenergized by tests or other means and grounds applied. Grounding requirements for deenergized circuits are found in the National Electrical Code (NEC) and the National Electrical Safety Code (NESC). Lockout/tagout requirements are discussed at length in Section 12 of EM 385-1-1, Control of Hazardous Energy. When there is no choice other than to perform work on energized circuits or equipment, protective equipment meeting ANSI/ASTM standards shall be used. This protective equipment together with its required care and testing is described in Par. 05.H, Electrical Protective Equipment in EM 385-1-1.

8. That portion of the low voltage accidents which are caused by defective power tools, faulty electrical cords, defective outlets and electric lights can virtually all be prevented on Corps projects if we rigidly require that all electrical tools be operated only on ground fault circuit interrupter (GFCI) protected circuits; by ensuring that the GFCIs are regularly tested to prove they are functional; by ensuring that the contractor inspects all temporary wiring before it is placed in service; and by ensuring that all temporary electrical cords are inspected prior to their entry on the job site and that they are protected from damage during their use. Damaged electrical equipment must not be used on Corps projects.

9. The majority of high voltage electrocutions that involve non-electrical work usually involve inadvertent contact with an energized circuit. Classic examples are the use of a crane in close proximity to an overhead electrical distribution line or an excavation in the vicinity of an unknown underground electrical distribution system with resultant contact with the high voltage circuit. To minimize the potential for accidents of this type, the "plan-in-hand" portion of the biddability, constructability, operability and environmental review should ensure that existing overhead or underground electrical lines are shown on the contract drawings so that the successful bidder is aware of work restraints in the project area. Work in the proximity of overhead electrical lines should be addressed in the activity hazard analysis for that phase of work. The weekly toolbox meetings should address work in the proximity of electrical lines during that phase of work. Methods of working which do not allow potential contact with electrical lines should be required, i.e., placement of a crane in such a location that the boom travel cannot reach an overhead line by maintaining the minimum clearances specified in EM 385-1-1, Par. 11E, Operations Adjacent to Overhead Lines. Excavation should never be started without contacting the utility company or DPW/BCE for assistance in locating underground lines.

10. We should always be cognizant of potential electrical hazards and which types historically have contributed to the most accidents. An electrical hazard does not have a distinctive smell as does a natural gas leak. It is not visible in the manner that a hot water

or steam leak may be nor can you feel it as you would a hot surface as you came close to it before touching it. It is also, in the absence of a fault or short circuit, usually silent. However, an instant's carelessness or an inadvertent contact with a energized circuit can result in irreparable damage to the human body. Remember, electrical accidents have historically caused the second highest number of fatalities on Corps construction projects.

11. The statistics and technical data for this CB were extracted from the May 1995 issue of the CEE News and from the audio/visual aids used by Sara McGraw of Mobile District in her presentation at the Sixth Worldwide Area/Resident Engineers Workshop. This CB has been coordinated with the following HQUSACE organizations: Safety and Occupational Health Office (CESO-ZA) and Engineering Division (CEMP-ET).

CR Schroer
CHARLES R. SCHROER
Chief, Construction Division